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# Green-Charcoal

**Pro-Natura International has developed a continuous process of pyrolysis of vegetal wastes (agricultural residues, renewable wild-grown biomass) transforming them into green carbon. This domestic fuel performs the same as charcoal made from wood, at half the cost.**

**It represents a freeing up from the constraints of scarcity, distance and cost of available fuels in Africa.**

**The machinery required for the process is of modest scale and functions on practically no outside energy and no emission of toxic fumes, it only takes 8 kW of electric power. When run by two persons, it can produce more than 3 tonnes of green charcoal a day.**

Two million people worldwide face domestic energy shortages. In many parts of Africa, Latin America and Asia, including India and China, wood is becoming harder and harder to find and modern energy supplies are non-existent. In the Sahel, for example, the women have to walk on average 20 km each day to find the household supply of wood and in the towns families have to spend a third of their income on wood or charcoal. At the same time, the exclusive use of wood for energy increases deforestation which dramatically increases the problems of drought and deforestation.

The disappearance of forests protecting watersheds leads to more variability and thus less availability of surface waters, and diminishes water infiltration supplying aquifers. In addition, the loss of vegetative cover also increases hydraulic and wind erosion, and can start the process of soil laterisation, destroying fertility.

The Green-Charcoal project precisely meets the recommendations of the international Convention against desertification, paragraph 19/1 (f.) "...utilisation... in particular of renewable energy sources, supply of appropriate technologies to reduced dependence on fire wood."
A *sine qua non* condition for halting deforestation in the savannah zones is to introduce the possibility to cook with a sustainable fuel source, different from wood or charcoal.

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Green-Charcoal as a cooking fuel is a considerable improvement in combating the widespread rural problem of indoor air pollution mortality (1.6 million of deaths a year).
The use of the Green-Charcoal machine is a significant improvement towards reducing the greenhouse gas intensity that is associated with the normal production of charcoal from wood. The improvement from using the Green-Charcoal machine is due to the fact that the process burns the methane produced as its driving source of energy.

## An innovative technology for renewable household energy

The objective of the project is to promote a new technology (Green-Charcoal), patented and developed by Pro-Natura International, producing a household fuel alternative to wood, and derived from agricultural residues not used for animal foodstuffs.
Numerous attempts to carbonise biomass failed for reasons of pyrolytic gas emissions during combustion. These gases are carcinogenic and pose a health risk whilst cooking.
Contrary to these experiments, Pro-Natura proposes a domestic fuel made from Green-Charcoal, obtained by a unique and efficient carbonisation procedure, which demonstrates the following positive benefits, which allow fuel wood to be replaced by Green-Charcoal at a very competitive price.

This project has two objectives:

• **Ecological**
By reducing dependence on firewood, the project protects forests and as a consequence will help to halt desertification. In addition, and contrary to traditional wood charcoal production, the carbonisation process does not emit any methane (see annex). It must be noted that, in contrast to wood, Green-Charcoal production does not emit any toxic fumes.

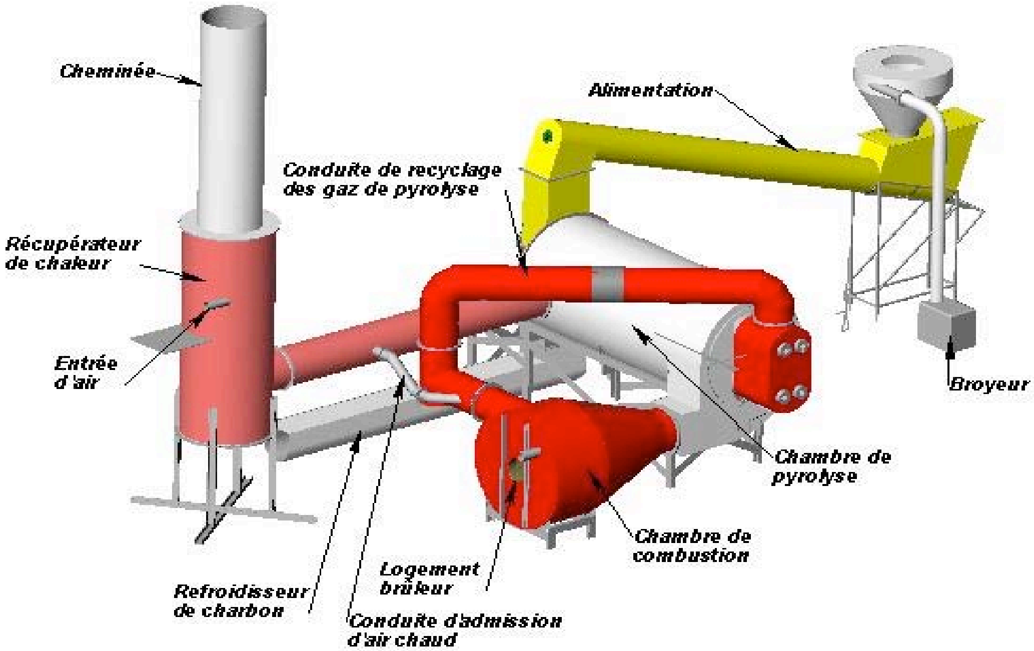
• **Economic**
Supplying third world population with a new high quality household fuel cheaper than charcoal will, by the same token, create sustainable development in the regions in question, based on a new, local agro-industrial business.

## The carbonisation of biomass takes place on a continuous basis

This process is based on the carbonisation of vegetative material on a continuous basis and on agglomeration of the carbon into balls, pellets or briquettes. Other attempts made to carbonise biomass on a batch-processing basis to date have all failed due to mechanical reasons or low energy yields. The continuous carbonisation process proposed by Pro-Natura, developed in collaboration with the society Pro-Natura has resolved these problems.
Savannah weeds, reeds and various types of straw (wheat, rice or maize), cotton stems, rice husk, coffee husk, bamboo, or more generally all plants with a sufficient lignin content can be used to produce Green-Charcoal. The technology developed by Pro-Natura is based on the utilisation of a reactor heated to 500°C.
Through which the biomass flows continually, the temperature being maintained at a constant level by the combustion of pyrolytic gases that are recycled and burnt in a second reactor.
One of the unique features of the process is that once the machine is pre-heated, the process produces its own energy, except for the agitation of the biomass that is obtained from a small electrical motor of low consumption.

This process is therefore practically autonomous in terms of energy and its yield reaches 30% to 50% depending on the type of biomass (weight of charcoal compared to gross weight of biomass).
One important aspect of the design of the carboniser is the external insulation that must be as good as possible to ensure that the heat generated by the combustion of the pyrolytic gases is sufficient to maintain the temperature of the reactor around 500°C.
Per unit of heat produced, the Green-Charcoal is far cheaper than wood charcoal.

**Green-Charcoal briquettes**

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## The climate change mitigation potential

While equivalent to wood charcoal in terms of calorific properties, green-charcoal presents various advantages:

1. Alleviating the pressure on natural dry forests by substituting wood fuel with other biomass;
2. Improving carbonization yield (33%) compared to traditional charcoal making (about 10%);
3. Eliminating $CH_4$ emissions that is usual in traditional carbonization.

The project is a Small-scale CDM-project. More precisely it is a “Type (iii) project activity”, i.e. a project activity that both reduces anthropogenic emissions by sources and directly emits less than 15 kilo tonnes of carbon dioxide equivalent annually (see decision 17/CP.7, paragraph 6 (c) (iii)).
The possible lifetime of the baseline is 20 years.
Sources taken into account for the baseline:

- Avoidance of deforestation related to the production of wood charcoal;
- Avoidance of $CH_4$ emissions resulting from traditional wood charcoal production techniques;
- Abatement of $CO_2$, $CH_4$ and $N_2O$ emissions resulting from the burning of agricultural residues.

Estimated emissions reductions are based on the most conservative assumptions:

- **Avoided deforestation per ton of charcoal:** 5.5 tons of dry wood that corresponds after computation to about 11.6 $tCO_2$-equivalent.
- **Avoided $CH_4$ emissions per ton of charcoal produced:** 0.67 $tCO_2$-equivalent. This data, taken from the PCF Plantar project, is used as proxy. It is a conservative figure as techniques used in the Plantar Project to produce charcoal are much more efficient than those in Niger.
- **Avoided burning of unused biomass:** allows for a reduction of 0.06 kg of $CO_2$-equivalent per ton of biomass used in the charcoal production process.

Pro-Natura will follow guidelines of Appendix B related to simplified modalities and procedures for small-scale CDM project activities. More specifically, it will abide with paragraph 19 of these guidelines: "For renewable energy technologies that displace non-renewable sources of biomass, the simplified baseline is the non-renewable sources of biomass consumption of the technologies times an emission coefficient for the non-renewable sources of biomass displaced".

See below the calculations leading to the evaluation of carbon credits generated per year by a Pyro-7 machine: 12,45 kg of $CO_2$ equivalent per kg of green-charcoal, i.e. 13,700 tonnes of $CO_2$ per year.

## Carbon Generation

| | | |
|---|---|---|
| Green charcoal production | t/year | 4 712 |
| Yield | % | 33,33% |
| Biomass input | t/year | 14 137 |

| Avoided deforestation | Unit | |
|---|---|---|
| Baseline emissions | tCO2/year | 54 644 |
| Charcoal/dry wood ratio | t charcoal/t dry wood | 0,18 |
| Humidity content of wood | % | 15,00% |
| Avoided wood deforestation | t/year | 29 806 |
| Carbon content | tC/year | 14 903 |
| Project emissions | tCO2/year | 0 |
| ERs | tCO2/year | 54 644 |

| Avoided methane emissions | Unit | |
|---|---|---|
| Baseline emissions | tCO2e/year | 3 157 |
| CO2e/charcoal ratio | % | 67% |
| Project emissions | tCO2e/year | 0 |
| ERs | tCO2/year | 3 157 |

| Avoided biomass burning | Unit | |
|---|---|---|
| Baseline emissions | tCO2e/year | 848 |
| CO2e/biomass ratio | kgCO2e/t | 0,06 |
| Project emissions | tCO2e/year | 0 |
| ERs | tCO2/year | 848 |

| | | |
|---|---|---|
| Avoided deforestation | tCO2/year | 54 644 |
| Avoided methane emissions | tCO2/year | 3 157 |
| Avoided biomass burning | tCO2/year | 848 |
| TOTAL ERs | tCO2e/year | 58 650 |

| | | |
|---|---|---|
| ERs per unit of charcoal | kgCO2e/kg charcoal | 12,45 |

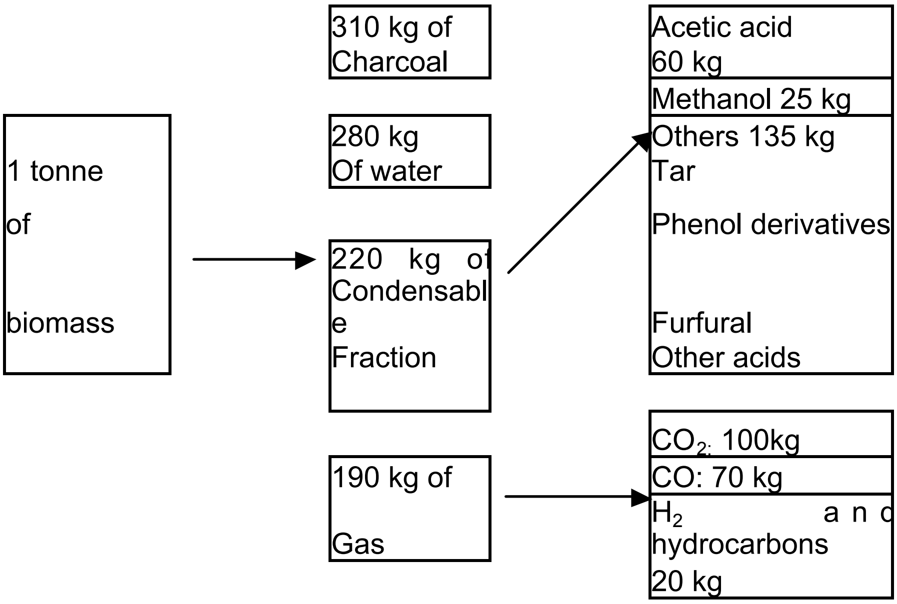
# Technical aspect of Green-Charcoal

## 1. Overview of pyrolysis

Pyrolysis or carbonisation is defined as the irreversible thermo-chemical reaction that is started by re-heating in the absence of air to start it and to trigger endothermic and exothermic reactions. The biomass produces, as a product of the pyrolysis process under normal conditions, a mixture of gas, liquid and charcoal.

### 1.1. Global balance of carbonisation

As an indication, in the table below, the global results of carbonisation of one tonne of biomass (at 20% gross water content) gives:

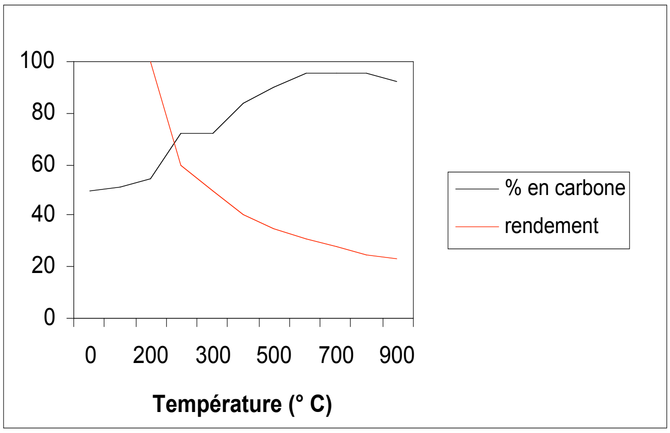



### 1.2. Different phases of carbonisation depending on temperatures and the compromise between quantity and quality

The following table and figure summarise the evolution of carbon content and calorific value as a function of temperature during carbonisation, after the study carried out by BRIANE and DOAT [3].

| Carbonisation steps | Water loss | Release of Oxygen gas | Start of Release of hydrocarbons | Hydrocarbon Phase Cm Hn | Dissociation |
|---|---|---|---|---|---|
| Temperature °C | 150-200 | 200-280 | 280-380 | 380-500 | 500-700 |
| Carbon content (%) | 50-60 | 60-70 | 70-78 | 78-85 | 85-90 |
| Calorific value (kcal/m$^3$) | 1,100 | 1,210 | 3,920 | 4,780 | 3,630 |

These results therefore show that the composition of charcoal produced depends on the temperature of the reaction achieved during combustion. The chemical quality of charcoal (% of fixed carbon) increases with the temperature to the detriment of the yield production (biomass/charcoal). Indeed, the loss of volatile matter is all the more important since the temperature of the reaction is high, which implies an increase in the rate of fixed carbon and a drop in the yield production (see following figure).
As a consequence, for the production of Green-Charcoal, a compromise must be made between the qualitative and quantitative aspects.




## 2. Carbonisation techniques

Three operational modes of carbonisation can be distinguished:
- Carbonisation by partial combustion;
- Carbonisation by injection of hot gas in the load;
- Carbonisation in an enclosed reactor.

**2.1. Partial combustion furnaces**
For this technique, the energy required for carbonisation is provided by the combustion of part of the load, placed inside a sealed enclosure, which reduces the yield of wood charcoal at the same rate. All condensable products as well as gases are usually not recovered. The transformation of wood into charcoal by this method is poor, since over 50% of the initial energy is lost.

Furthermore, the inconvenience of this method is that it does not allow carbonisation of straw, reeds or cotton stems as well as biomass of weak granulometry such as rice husks, coffee husks and sawdust. The main reasons are:

- Poor thermal transfer in the carboniser load;
- Appearance of chimneys in the load prevents lateral thermal transfer in the case of straw;
- Difficulty in controlling air entries, which can potentially lead to total inflammation of the load.

**2.2. Carbonisation by contact with hot gases**
The energy required for carbonisation is provided by the hot gases coming from an external source and coming into direct contact with the load. This method has a good production yield of around 30 to 35% but the cost of installation remains quite high. It is also important to note that the functioning of these reactors is difficult to control without adapted equipment.

### 2.3. Carbonisation in a reactor

The load is placed in a sealed enclosure, the energy required for carbonisation being provided by an external heat source, which is transmitted by the walls of the enclosure. The source can be fed by any combustible materials. Once the carbonisation process is started, the pyrolytic gases can be injected into the source to sustain pyrolysis.
The advantage of these reactors is the ability to carbonise vegetative materials of weak granulometry and to achieve a production yield around 35%.

## 3. The choice of carbonisation in reactor and the advantage of the Pro-Natura technology

It has been very easy for us to choose the technique of carbonisation in reactor. The principal reasons are:

- The valorisation of all types of lignaceous vegetative materials with non-negligible energy content, therefore a biomass which can be of weak granulometry;
- A superior production (biomass / charcoal);
- A superior energy yield thanks to recovery of pyrolytic gases.

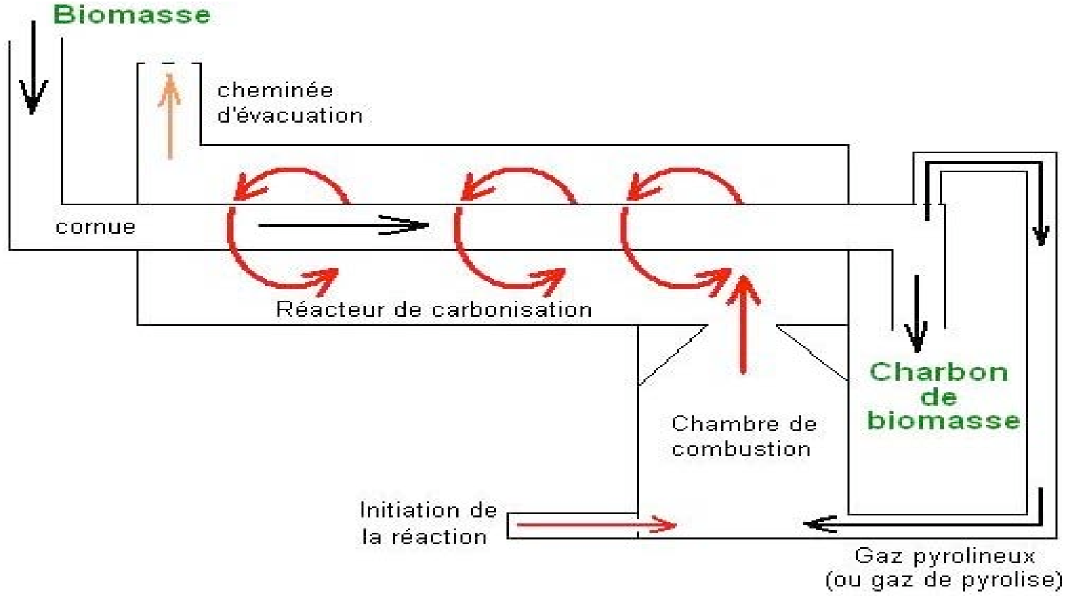
### 3.1. The Pro-Natura technology

As well as the advantages of the carbonisation in-reactor process, Pro-Natura has managed not only to lower the running costs of the reactor by continuous production, avoiding in this way stopping the machine each time charcoal needs to be recovered. This process also allows optimum energy yields to be obtained, regarding carbonisation in reactor, thanks to the excellent control of the combustion of pyrolytic gases, assuring autonomous function of the reactor. Complete combustion of the pyrolytic gases, with this technology, allows not only to have a constant carbonisation temperature around 550°C for biomass having a maximum moisture content of 15%, but also to be able to have heat extraction used for either:

- Pre-heating a second reactor;
- Running a dryer;
- Producing overheated steam to turn a turbine and therefore an alternator to produce electricity.

### 3.2. Ecology

• The functioning of this reactor does not release greenhouse gases;
• The charcoal produced, whilst burning, does not emit gases toxic to humans thanks to its good chemical quality (very high carbon content);
• The use of biomass in place of wood as household fuel protects the forests and helps, as a consequence, the fight against desertification.




## 4. Description of the reactor

**4.1. Supply**
The supply is composed of a 3 m$^3$ silo mounted above a screw with a broken thread to obtain a tight seal preventing the re-entry of pyrolytic gases.
Beneath, this 3 m long and 250 mm screw (in the case of fluid biomass rice or coffee husks) is linked to the reactor by a pipe, rectangular in cross-section. The dimensions of these elements vary according to the biomass to be treated.

**4.2. Carbonisation reactor**
The reactor is composed of two enclosures, each 30 cm in diameter and 2.5 m long, placed in parallel and linked by a removable pipe of 15 cm in height and 30 x 40 cm$^2$ in section.
The exchange area, for each enclosure, which corresponds to 2.2 m in length for a diameter of 30 cm, is located in a cylinder (envelope) of 1 m diameter and 2.2 in length. The assembly of the enclosures and the envelope is achieved by a press, to assure the dilations of the unit but also easy removal of the enclosures. Chicanes are lodged in the space between the enclosures and the envelope, in order to increase the residence time of the combustion gases. The steel used is of 25/20 refractory sheets of 3 mm thickness and the ceramic fibre of 100 mm thickness assures thermal isolation.
A 25 mm thick layer of high temperature ceramic fibre coats the internal surface of the envelope to protect it from the radiation.
Transporting screws driven by a 3 kWh motor with a profile adapted to the biomass are mounted in the enclosures. The mounting of screws is achieved from one side on tight platforms with special high temperature cast iron rings and on the other side on presses.
Regarding the circulation route of the biomass once it has left the feeder screw, it passes first into the top enclosure and secondly into the lower enclosure, situated just below after passing through the linking pipe.

**4.3. Combustion reactor**
The combustion reactor is made from black steel with interior protection in refractory concrete (type HT 3500) of 10 cm thickness. In this reactor, of 900 mm diameter and 500 mm length then converging over 800 mm length to be assembled to the carbonisation reactor, the combustion of the pyrolytic gases occurs during carbonisation.

The combustion of the fuel oil also occurs thanks to a burner used uniquely for pre-heating.
A 500mm long and 400mm diameter post-combustion reactor mounted at an angle to the principle reactor assures a good mixture of hot air from the heat recovery, and of pyrolytic gases from biomass carbonisation.

**4.4. Combustion chamber for the treatment of excess pyrolytic gases**
That chamber has a diameter of 700 mm and is 800 mm long with a lining of refractory cement. The treatment of the excess gases is assured by an input of hot air from the heat exchanger placed inside the chimney.
The fumes can be used in a drying facility.

**4.5. Chimney and heat recovery**
The chimney has a 80 cm diameter over 4 m high then 40 cm over 2 m in normal steel, protected on the inside by a coating of ceramic fibre of 25 mm thickness. In this chimney a heat recovery unit is mounted, in the shape of a pin, and made of stainless steel tubes of 88mm diameter. The air circulating in this exchanger, necessary for the combustion of pyrolytic gases, is blown by a centrifuge vent.

**4.6. Recuperation of charcoal**
The charcoal obtained after carbonisation of the biomass is transported by a screw of 4 m length to be stored in a skip. On the other hand, before safely storing the charcoal, a water jet system has been installed along the screw in order to reduced the temperature from the 480°C at the exit of the reactor.

## 5. Functioning of the reactor

**5.1. Thermal circuit**
The ignition of the reactor consists of pre-heating with a fuel oil burner to achieve a temperature of 560°C in the carbonisation reactor. Once this 'carbonisation temperature' is obtained, the enclosures are fed with biomass of 15% moisture content (see mechanical circuit).
Maintaining this temperature and the autonomous temperature of the reactor is only assured by the combustion of gases produced by the pyrolysis of biomass in the enclosures. As a consequence, for good machine functioning and an optimum yield, it is advised to keep a very regular feed.
Perfect combustion of the pyrolytic gases is assured by a good gas mixture – hot air in a specially designed burner for poor gases. This air, at 400°C, comes from the recovery of heat from the chimney.

**5.2. Mechanical circuit**
The transport and complete carbonisation of the biomass are assured by the profile of the screws and the speed of transfer. This speed varies depending on the type of biomass used. A regular feed of biomass at 10% moisture content allows a maximum production rate, but also thermal stability of the reactor, guaranteeing totally autonomous functioning without human intervention.

## 6. Agglomeration of the fines of Green-Charcoal

After carbonisation, the Green-Charcoal produced does not burn easily in the fireplaces. An agglomeration of these charcoal fines will therefore be necessary to allow easier combustion and transport of the briquettes obtained. As a consequence it seems useful to present the different techniques for agglomeration of the charcoal fines. These techniques can be split into two major groups: compression techniques and non-compression techniques (pellet making).

With the exception of the process by extrusion, the manufacture of briquettes or pellets of charcoal requires a binder to mix with the fines. The combustibles, still very humid, then pass through a drying over in order to eliminate water, after which they are solid enough to be used in domestic ovens and fires.

### 6.1. Compressing techniques

**• Briquette manufacture**

This is the production of briquettes or compressed products of medium size by compressing action. The most frequently used technique of briquette production consists of compressing the mixture of fines with 8 to 10% of binder between two revolving rollers fitted with alveolus on their external surfaces. The Rassant press also exists, but the production rate is modest. The process consists of compressing the fines with 10% binder, located in a sleeve, up to 15 tonnes/$cm^2$. The briquette is then recuperated by simple extraction in the lower tray of the press.

**• Extrusion**

Extrusion consists of pushing the material to be agglomerated through orifices of given shapes and dimensions. An endless screw or a piston can force the substrate into the slightly conical extrusion orifice. In a screw-based extrusion system, there is usually electrical resistance around the channel to enable the non-carbonised products temperature to rise. The tar emissions by torrefaction of this biomass will serve as the binder. The product leaves in the form of a continuous sausage, which will then be chopped to the desired length.

### 6.2. Pellet manufacturing

This non-compression technique consists of agglomeration of particles and turning them into ball or pellet form. The transformation is achieved in a granulating tray that is a short cylinder, tilted a few degrees over the horizontal and agitated by a motor of variable speed.

Under the action of rotation and with the addition of a wetting agent (a mixture of water and 6% starch), the small particulates agglomerate and form spherical bodies.

### 6.3. Agglomeration in general

Some of these agglomeration techniques are still very much used in industry but they remain quite difficult to break even in certain areas of activity.

Indeed, in certain cases of charcoal fines agglomeration, for example the balance between the purchase price of machinery, running costs and essential repairs for wear and tear caused by certain very abrasive products remains very difficult to equilibrate with briquette production.

As a consequence, it is absolutely necessary to fully study all parameters, which are: type and quantity of charcoal to agglomerate, the demand market and the machine running costs, in order to choose the most appropriate agglomeration technique.

The choice of binder is also an essential element affecting the quality of the briquettes, but choice is limited by several constraints: local availability, cheapness and non-toxic properties during combustion.